COST–EFFECTIVENESS: AN INTRODUCTION AND OVERVIEW

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The need for considering cost in relation to effectiveness must have occurred to the earliest planners. Cost–effectiveness is not a catchword to suggest we are doing something new; at most we are doing something better. What is novel about cost–effectiveness analysis today, and what brings us together, is the marvelous refinement of the methods for relating cost to effectiveness that has taken place in the last few years and the acceptance of these methods as an aid to decisionmaking at high policy levels. By this Symposium we hope to make clear the scope of cost–effectiveness analysis and to discuss its problems and limitations in order that we may broaden its scope and increase its acceptance.

DEFINITIONS

What is a cost–effectiveness analysis? Broadly defined (too broadly for my taste) it is any analytic study designed to assist a decisionmaker identify a preferred choice from among possible alternatives. In a military context, typical analyses might tackle such questions as the extent to which aircraft should be repaired at a depot rather than on the base; the possible characteristics of a new strategic bomber and whether one should be developed or not; whether tactical air wings or carrier task forces should be substituted for U.S. ground divisions in NATO; or whether we should modify the test ban treaty now that the Chicoms have nuclear weapons

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and, if so, how. Each such analysis involves as one stage a comparison of alternative courses of action in terms of their costs and their effectiveness in attaining some specific objective. This is cost-effectiveness analysis, narrowly defined. Usually it consists of an attempt to minimize dollar cost subject to some mission requirement (which may not be measurable in dollar terms) or, conversely, to maximize some physical measure of output subject to a budget constraint.

Since this comparison often receives the lion's share of attention by the participants, by a natural extension, the entire study is called a cost-effectiveness analysis. But such emphasis is likely to be misplaced in an analysis designed to furnish policy advice. Other facets of the problem may be of greater significance to its solution: the specification of the right objectives, the determination of a satisfactory way to measure performance, the influence of the nondollar costs, or the discovery of better alternatives.

Let me try to illustrate this last point with a homely example.

Suppose a family has decided to buy a television set. Not only is their objective fairly clear, but, if they have paid due attention to the advertisements, their alternatives are well-defined. The situation is then one for cost-effectiveness analysis, narrowly defined. The only significant questions the family need answer concern the differences among the available sets in both performance and cost. With a little care, making proper allowance for financing, depreciation, and maintenance, they can estimate, say, the five year procurement and operating cost of any particular set and do so with a feeling that they are well inside the ball park. They will discover, of course, that finding a standard for measuring the performance of the various sets is somewhat more difficult. For one thing, the problem is multidimensional—they must consider color quality, the option for remote control, portability, screen size, and so forth. But, ordinarily,

one consideration—perhaps color—dominates. On this basis, they can go look at some color sets, compare costs against color quality, and finally determine a best buy.

Now suppose the family finds they have more money to spend and thus decide to increase their standard of living —a decision similar to one to strengthen the U.S. defense posture by increasing the military budget. This is a situation for a broader analysis. They first need to investigate their goals or objectives and look into the full range of alternatives —a third car, a piano, a country club membership. They then need to find ways to measure the effectiveness of these alternatives and establish criteria for choice among them. Here, because the alternatives are so dissimilar, determining what they want to do is the major problem; how to do it and how to determine what it costs may become a comparatively minor one.

To distinguish this broader analysis from a narrow cost-effectiveness comparison, I call the former a "systems analysis." Numerous other terms—operations analysis, operations research, systems engineering, cost-utility analysis—might also be used, depending on the context, and, to different people, they might imply some subtle distinction. But they all convey the same general meaning. Moreover, there exists between them no distinctions in principle. Whatever differences may be found are simply matters of degree, emphasis, and context. What is important for our discussion, therefore, is the characteristics they have in common. These include an effort to make comparisons systematically in quantitative terms using a logical sequence of steps that can be retraced and verified by others.

In essence, what I am saying is that to qualify as a complete analysis a study must look at the entire problem and look at it in its proper context. Characteristically, such an analysis will involve a systematic investigation of the decisionmaker's objectives and of the relevant criteria; a comparison—quantitative where possible—of the costs, effectivenesses, risks, and timing associated with the alternative policies or strategies for achieving each objective; and an

attempt to formulate additional alternatives if those examined are found wanting. Although I prefer "systems analysis" for the broader analysis, in what follows I'll use the term cost-effectiveness for the full range, broad and narrow, of analytic approaches to problems of choice.

THE ESSENCE OF THE METHOD

What is there about an analytic approach that makes it better or more useful than other ways to furnish advice—than, say, an expert or a committee? In areas, such as defense planning, where there is no accepted theoretical foundation, advice obtained from experts working individually or as a committee depends largely on subjective judgment. So does the advice from cost-effectiveness analysis. But the virtue of analysis is that it is able to make a more systematic and efficient use of judgment than any of its alternatives. The essence of the method is to construct and operate within a "model"—an idealization of the situation appropriate to the problem. Such a model—which may take such forms as a computer program, a war game, or a set of questionnaires—introduces a precise structure and terminology that serve primarily as a means of communication, enabling the participants in the study to make their judgments in a concrete context. Moreover, through feedback—the results of computation, the counter-moves in the war game, or the answers to the questionnaires—the model helps the decisionmaker, the analysts, and the experts on whom they depend to revise their earlier judgments and thus to arrive at a clearer understanding of the problem and its context.

The central importance of the model can be seen most readily, perhaps, by looking at its relation to the other elements of analysis. There are five altogether. Each of them is present in every analysis of choice, although they may not always be explicitly identified.

1. The objective (or objectives). Cost-effectiveness analysis is undertaken primarily to help choose a policy or course of action. One of the first and most important tasks of the analyst is to attempt to discover what objectives the decisionmaker is, or should be, trying to attain through this policy, and how to measure the extent to which they are, in fact, attained. This done, strategies, forces, or equipment are examined, compared, and chosen on the basis of how well and how cheaply they can accomplish these objectives.

2. The alternatives. The alternatives are the means by which it is hoped the objectives can be attained. They need not be obvious substitutes for one another or perform the same specific function. Thus, to protect civilians against air attack, shelters, "shooting" defenses, counter-force attack, and retaliatory striking power are all alternatives.

3. The costs. The choice of a particular alternative for accomplishing the objectives implies that certain specific resources can no longer be used for other purposes. These are the costs. In analyses for a future time period, most costs can be measured in money, but their true measure is in terms of the opportunities that they preclude. Thus, if we are comparing ways to eliminate guerrillas, the damage to nonparticipating civilians caused by the various alternatives must be considered a cost, for such damage may recruit more guerrillas.

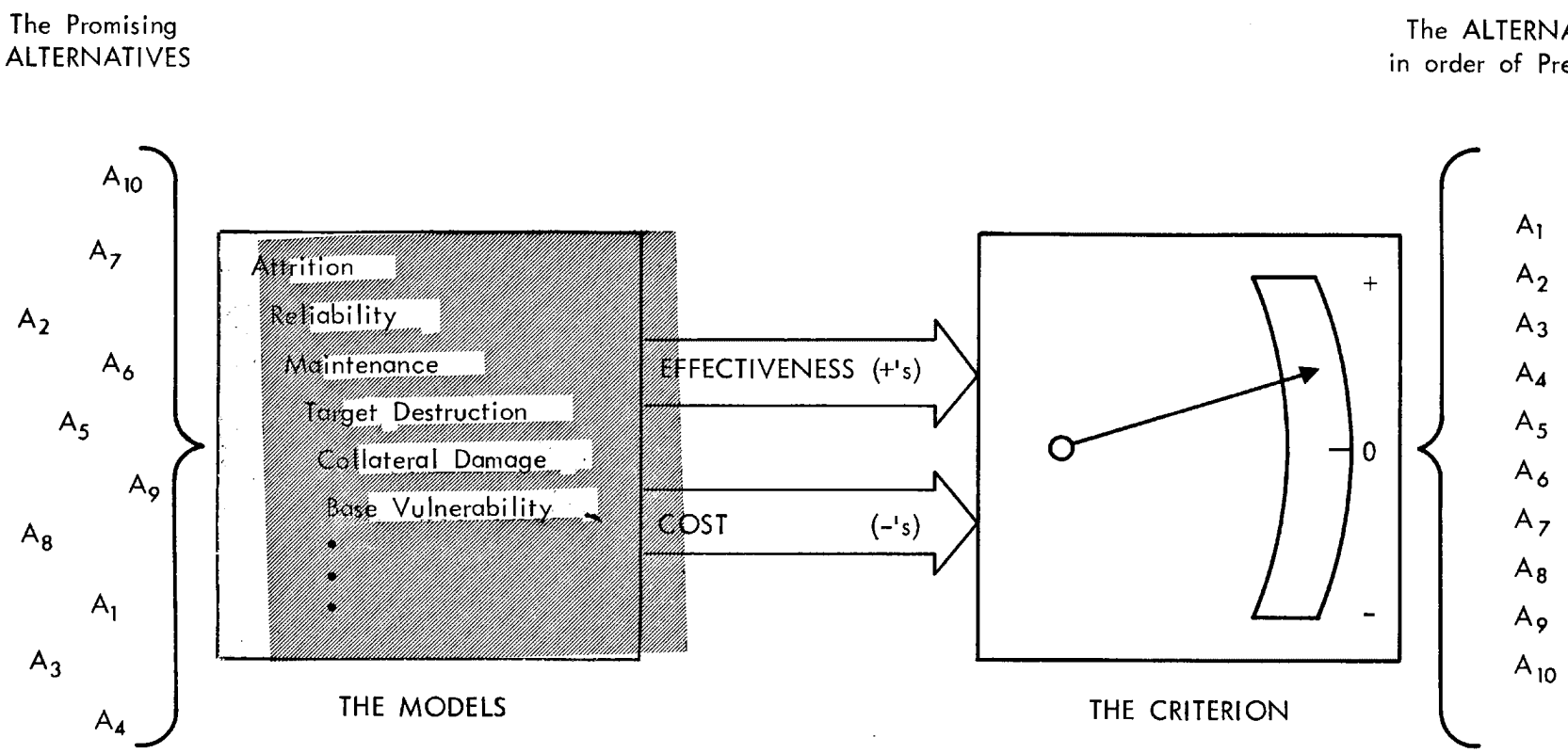
4. A model (or models). A model is a simplified representation of the real world which abstracts the features of the situation relevant to the question being studied. The means of representation may vary from a set of mathematical equations or a computer program to a purely verbal description of the situation, in which judgment alone is used to predict the consequences of various choices. In cost-effectiveness analysis (or any analysis of choice), the role of the model

(or models, for it may be inappropriate or absurd to attempt to incorporate all the aspects of a problem in a single formulation) is to predict the costs that each alternative would incur and the extent to which each alternative would assist in attaining the objectives.

5. A criterion. A criterion is a rule or standard by which to rank the alternatives in order of desirability and choose the most promising. It provides a means for weighing cost against effectiveness.

Having formulated and researched the problem—that is, clarified the issues, limited the extent of the inquiry, searched out the necessary data and relationships, and identified the various elements—the process of analysis may be outlined as follows. (See chart.) The consequences of choosing an alternative (which may have to be discovered or invented as part of the analysis) are obtained by means of the models. These consequences tell us how effective each particular alternative is in the attainment of the objectives (which requires that we have a measure of effectiveness for each objective) and what the costs are. The criterion can then be used to arrange the alternatives in order of preference.

Unfortunately, things are seldom so tidy: alternatives are not adequate to attain the objectives; the measures of effectiveness do not really measure the extent to which the objectives are attained; the predictions from the model are full of uncertainties; and other criteria which look almost as attractive as the one chosen may lead to a different order of preference. When this happens, we must begin again. The key to successful analysis is iteration—a continuous cycle of formulating the problem, selecting the objectives, designing better alternatives, collecting data, building new models, weighing cost against performance, questioning assumptions and data, reexamining the objectives, opening new alternatives, and so on until satisfaction is obtained or time or money forces a cut-off.



The structure of analysis

THE VIRTUES

In stating the purpose of cost-effectiveness analysis, we have, in a sense, said what it can do. It can be applied to a range of problems extending from the very narrow to the very broad. At one end of the range, it may be applied to determining how much of the Air Force construction budget allocated to hangars should be assigned to a given base, or whether the electrical maintenance shop should be amalgamated with some other shop, or what type of all-weather landing system should be installed in a new transport aircraft. At the other end, it can help to decide how much should be spent on national defense, or how the defense budget should be allocated between strategic and general purpose forces, or whether the additional capability provided by another carrier task force would be worth the cost. It is essential: without calculation there is no way to discover how many missiles may be needed to destroy a target system, or how arms control may affect security. This is not to say that every aspect of such problems can be quantified or that analysis is without limitations, but only that it is not sensible to formulate national defense policy without careful consideration of whatever relevant numbers can be discovered.

It is easy, unfortunately, to exaggerate the degree of assistance that analysis can offer a policymaker. In almost every case, competent cost-effectiveness analysis can help a decisionmaker to understand the relevant alternatives and the key interactions by giving him an estimate of the costs, risks, and possible payoffs associated with each course of action. In so doing, it may sharpen his intuition; it will certainly broaden his basis for judgment. This almost always helps the decisionmaker make a better decision than he would otherwise make, but value judgments, imprecise knowledge, intuitive estimates of enemy intent, and other defects mean that a study can do little more than assess some of the implications of choosing one alternative over another. In practically no cases, therefore, should the analyst expect to demonstrate to a decisionmaker that, beyond all reasonable doubt, a particular course of action is best.

THE LIMITATIONS

Every systems analysis has defects. Some of these are limitations inherent in all analysis of choice. Others are due to the difficulties encountered in coping with such things as the varying times at which alternatives become available or uncertainty about the enemy. Still others are flaws or errors which, hopefully, will disappear as we learn to do better, more thorough, and complete analyses.

It is important to remember that all analysis of choice falls short of scientific research. No matter how we strive to maintain standards of scientific inquiry or how closely we attempt to follow scientific methods, we cannot turn cost-effectiveness analysis into science. Its objective, in contrast to that of science, is primarily to recommend—or at least to suggest—policy, rather than merely to understand and predict. Like engineering, it seeks to use the results of science to do things well and cheaply. Yet it differs from ordinary engineering in its enormous responsibility, in sometimes being forced by the nature or urgency of a problem to substitute intuition for verifiable knowledge, in the unusual difficulty of appraising—or even discovering —a value system applicable to its problems, and in the absence of ways to test its validity.

Except for this inability to verify, cost-effectiveness analysis may still look like a purely rational approach to decisionmaking, a coldly objective, scientific method free of the human attributes of preconceived ideas and partisan bias and judgment and intuition.

It isn't, really. Human judgment is used in designing the analysis; in deciding what alternatives to consider, what factors are relevant, what the interrelations between these factors are, and what numerical values to choose; and in analyzing and interpreting the results of the analysis. This fact—that judgment and intuition permeate all analysis—should be remembered when we examine the results that come, with apparent high precision, from analysis.

Most flaws are caused by such pitfalls as emphasis on working with the model instead of the question, or concentration on the type of uncertainty that can be treated analytically by Monte Carlo or other statistical techniques rather than on the real uncertainties, or neglect of the subjective elements in the analysis.

I'll elaborate on what I consider the most dangerous pitfall or source of defects. This is the attention bias. It is frequently caused by a cherished belief or an unconscious adherence to a "party line." All organizations foster one to some extent; RAND, the military services, and the DOD are no exception. My feeling is that Herman Kahn was right when he called the party line "the most important single reason for the tremendous miscalculations that are made in foreseeing and preparing for technical advances or changes in the strategic situation."* Examples of an attention bias are plentiful—the military planner whose gaze is so fixed on "winning" local wars that he excludes other considerations, or so fixed on maximizing deterrence that he completely disregards what might happen should deterrence fail; the weaponeer who is so fascinated by startling new weapons that he assumes they will of course be used; the State Department negotiator who seeks to conciliate the potential enemy at a military cost that is far too great, because he is unaware of it. In fact, it is this failure to realize the vital interdependence among political purpose, diplomacy, military posture, economics, and technical feasibility that is the typical flaw in most practitioners' approach to national security analysis.

Pitfalls are one thing, and the inherent limitations of analysis itself another. It is these limitations that confine analysis to an advisory role. I single out three for

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*H. Kahn and I Mann, Ten Common Pitfalls, The RAND Corporation, RM-1937, July 17, 1957, p. 42.

further comment: analysis is necessarily incomplete; measures of effectiveness are inevitably approximate; and ways to predict the future are lacking.

Analysis is necessarily incomplete

Time and money costs obviously place sharp limits on how far any inquiry can be carried. The very fact that time moves on means that a correct choice at a given time may soon be outdated by events and that goals set down at the start may not be final. This is particularly important in military analysis, for the decisionmaker can wait only so long for an answer. Other costs are important here too. For instance, we would like to find out what the Chicoms would do if we put an end to all military aid to Southeast Asia. One way to get this information would be to stop such aid. But while this would clearly be cheap in dollars, the likelihood of other costs precludes at once this type of investigation.

Still more important, however, is the general fact that, even with no limitations of time and money, analysis can never treat all the considerations that may be relevant. Some are too intangible. For example, such qualities of a system as its flexibility, its compatibility with other systems (including some that are yet to be developed), its contributions to national prestige abroad, and its impact on domestic political constraints can, and possibly should, play as important a role in the choice of alternative force postures as any idealized war outcome calculations. Ways to measure these things even approximately don't exist today and they must be handled subjectively. (And if we find out how to measure these things, other political, psychological, and sociological intangibles will still be left.) The analyst can apply his own judgment and intuition to these considerations and thus

make them part of the study, but the decisionmaker will rightly insist on applying his own.

Measures of effectiveness are approximate

In military cost-effectiveness analysis, measures of effectiveness are at best reasonably satisfactory approximations for measuring such vaguely defined objectives as deterrence or victory. Sometimes the best that can be done is to find measures which point in the right direction. Consider deterrence, for instance. It exists only in the mind—and in the enemy's mind at that. We cannot, therefore, measure directly the effectiveness of alternatives we hope will lead to deterrence, but must use instead such approximations as the potential mortalities that we might inflict or the square feet of roof cover we might destroy. Consequently, even if a comparison of two systems indicated that one could inflict 50 per cent more casualties on the enemy than the other, we could not conclude that this means the system supplies 50 per cent more deterrence. In fact, in some circumstances, we find arguments that the system which threatens the greatest number of casualties may provide the least deterrence!

Moreover, we can't be as confident about the accuracy of our estimates of effectiveness as we are about our cost estimates. It is the opinion of one analyst who is studying the problem of estimating casualties that if a pre-World War II estimator had worked analogously to his brother of today, had known his trade exceptionally well, had been knowledgeable about the means by which World War II military actions produced casualties, had known the probabilities associated with each weapon, and could have estimated the number of people subject to each weapon—then such an estimator would have underestimated

the total cost in human lives of the war to the Soviets by a factor of between three and four.

Such an error in the measurement of effectiveness may not be too important if we are comparing two systems that are not radically unlike one another—two ground attack aircraft, say. But at higher levels of optimization—tanks versus aircraft or missiles—gross differences in system effectiveness may be obscured by gross differences in the quality of damage assessment.

In brief, what I am saying is that we don't know how to translate a capability to create casualties (as perceived by the enemy) into deterrence, we don't know how they will compute the casualty-producing capability of our forces, and we don't even know how to do it ourselves very accurately. This is for a hard measure of effectiveness—the soft ones are worse!

Don't misunderstand me—the determination of even the dollar costs of a military action is not simple. The cost of a change in force posture, say, is measured by a price that typically includes the costs of R&D, initial investment, and annual operation, and these costs will have to cover the various weapons, equipment, and vehicles involved, and also the whole materiel and manpower structure that underlies the entire lifetime of the system. Consequently, it requires a great deal of sophistication to learn how to cost a force posture—to learn what things go into making up a posture and how their costs can be found. It takes even more know-how and research to estimate the costs of weapons and forces that are as yet only concepts. But with care and experience, once we decide <u>what</u> we are costing, we can do fairly well.

No satisfactory way to predict the future exists

While it is possible to forecast events to come in the sense of mapping out possible futures, there is no satisfactory way to predict a single future in terms of which we can work out the best system or determine an optimum policy. Consequently, we must consider a range of possible futures or contingencies. In any one of these we may be able to designate a preferred course of action, but we have no way to determine one for the entire range of possibilities. We can design a force structure for a particular war in a particular place, but we have no surefire way to work out a structure that is good for the entire spectrum of future wars in all the places they may occur.

Consequently, defense planning is rich in the kind of analysis that tells what damage could be done to the United States given a particular enemy force structure (or, to put it another way, what enemy requirements would be to achieve a given destruction); but it is poor in the kinds of analyses that evaluate how we will actually stand in relation to the Soviets in years to come.

THE PRESENT

In spite of their limitations, quantitative estimates of costs and effectiveness are clearly helpful to any intelligent discussion of national security. In current Department of Defense practice these quantitative estimates are obtained by means of cost-effectiveness analyses, sometimes assisted by computerized games. Many people, however, and some of you are probably among them, are vaguely uneasy about the particular way these estimates are made and their increasingly important role in military planning.

For example, an Air Force officer* writes that computer-oriented planning techniques are dangerous; that mathematical models of future wars are inadequate for defense planning; and that scientific methods cannot handle those acts of will which determine the conduct of war. A Congressman** says, "We should not allow cost-effectiveness to cost us our effectiveness in national security matters." A Senator*** remarks, "Our potential enemies may not use the same cost-effectiveness criteria and thus oppose us with the best weapons their technology can provide. This would create an intolerable peril to the national security."

Some of this skepticism may be justified, for the work may not always be competently done or used with its limitations in mind. But those critics who hold that national defense decisions are being made today solely by consideration of computer calculations are not only premature in their belief (to say the least), but probably have a basic misunderstanding of how such calculations must, in fact, always be used. As you should know, this process is today rampant with dogma, service rivalries, special interests, and horse-trading—so much so that, in the opinion of some analysts, a computerized solution based on a relaxation of these human constraints might lead to something better. But this is wishful thinking. As we have pointed out, analysis has limits. Broad problems always involve considerations which require reliance on judgment, intuition, and experience. And incidentally, the interservice rivalries and

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*Colonel Francis X. Kane, USAF, "Security is Too Important to be Left to Computers," Fortune Magazine, April 1964.

**Representative Laird of Wisconsin, Missile/Space Daily, April 7, 1964, p. 161.

***Senator John O. Pastore of Rhode Island, U.S. News and World Report, January 6, 1964.

bargaining are not all wasteful; they have the virtue of insuring that the work is carefully scrutinized and that alternatives and considerations to which we are blind through our cherished beliefs are brought to our attention.

THE FUTURE

Resistance by the military to the use of cost-effectiveness or systems analysis to help in broad problems of strategy is gradually breaking down. Military planning and strategy have always involved more art than science; what is happening is that the art form is changing from an ad hoc, seat-of-the-pants approach based on intuition and experience to one based on analysis supported by intuition and experience. With this change the computer is becoming increasingly significant—as an automaton, a process controller, a service trouble-shooting technician, a complex information processor, and a decision aid. Its usefulness in serving these ends can be expected to grow. But at the same time, it is important to note that even the best computer is no more than a tool to expedite analysis. Even in the narrowest military decisions, as we have just noted, considerations not subject to any sort of quantitative analysis can always be present. Big decisions, therefore, cannot become the automatic consequence of a computer program, of cost-effectiveness analysis, operations research, or any application of mathematical models.

For broad studies, involving force posture and composition or the strategy to achieve foreign policy objectives, intuitive, subjective, even ad hoc study schemes must continue to be used—but supplemented to an increasing extent by cost-effectiveness analysis. And as ingredients of this analysis, in recognition of the need for judgment, we can expect a greater use of techniques for the systematic employment of experts such as scenarios, gaming, and questionnaires,

along with an increasing use of computer-based analysis for problems where it is appropriate.

Moreover, the scope will broaden. Cost-effectiveness analyses must enter the domain of the social sciences. Here, as Olaf Helmer remarks in his perceptive essay, Social Technology:

> we are faced with an abundance of challenges: how to keep the peace, how to alleviate the hardships of social change, how to provide food and comfort for the inaffluent, how to improve the social institutions and the values of the affluent, how to cope with revolutionary innovations, and so on.*

Some of you evidently believe that cost-effectiveness analysis and related techniques can help with these problems, for later in this Symposium we will hear of applications to welfare and other government domestic programs. But to go very far into the domain of the social sciences, new techniques need to be developed. Indeed, as Helmer further remarks:

> many of the difficulties which beset our world today can be explained by the fact that progress in the social-science domain has lagged far behind that in the physical sciences.**

Now, while many people are extremely pessimistic about the possibilities of finding any techniques that will be really helpful, it is the thesis of Dr. Helmer that a completely pessimistic outlook is unwarranted:

> The potential reward from a reorientation of some of the effort in the social-science area toward social technology, employing operations-research techniques, is considerable; it may even equal or exceed in importance that of the achievements which are credited to the technologies arising out of the physical sciences.

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*Olaf Helmer, Social Technology, The RAND Corporation, P-3063. Paper presented at the Futuribles Conference in Paris, April 1965.

**Ibid.

> The methodological implications of such a reorientation can be simply summarized under the headings of "operational model building" and "systematic use of expertise".*

The first of these approaches is the essence of current cost-effectiveness analysis. The second is a necessary ingredient of the first that has just lately become the subject of research.

CONCLUDING REMARKS

How can we summarize any danger that there might be in reliance on cost-effectiveness analysis, or on any similar approach to broad government decisions? First, since many factors fundamental to problems of national welfare are not subject to rigorous, quantitative analysis, they may possibly be neglected, deliberately set aside, or improperly weighted in the analysis itself or in the decision based on such analysis. Second, an analysis may, on the surface, appear so scientific and quantitative that it may be assigned a validity not justified by the many subjective judgments involved. In other words, we may be so mesmerized by the beauty and precision of the numbers that we overlook the simplifications made to achieve this precision, neglect analysis of the qualitative factors, and overemphasize the importance of idealized calculations to the decision process. But better analysis and careful attention to where analysis ends and judgment begins should help to reduce these dangers. And without analyses we face these same dangers.

At the very least, cost-effectiveness analysis offers a way to choose the numerical quantities related to a weapon system so that they are logically consistent with each other, with an assumed objective, and with the calculator's expectation of the future. The method provides its answers by processes that are accessible

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*Ibid.

to critical examination, capable of duplication by others, and, more or less, readily modified as new information becomes available. And, in contrast to other aids to decisionmaking, which share the same limitations, it extracts everything possible from scientific methods, and its virtues are the virtues of those methods. But, even within the Department of Defense, its capabilities have as yet to be fully exploited.